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(54) **Solar concentrator**

(57) A space solar concentrator based on light-weight reflectors attached to the solar panel is described.

The integration of the reflectors allows for a high modularity. Solar panel deployment is not perturbed by the reflectors even with two-dimensional deployment concept. Each reflector consists in small saw tooth aligned as rows with solar cell rows in between.

Low concentration is achieved with a high level of thermal control and a high optical efficiency. When small off-pointing occurs, the solar flux distribution is still the same on each cells. It guarantees a good electrical control and management on the whole panel.

The reflector is preferably made of a thin film tight on a light-weight rigid frame deployed after launch. In another embodiment, the reflector is part of the panel substrate. The stowed configuration allows for superimposition of the solar panel.

High reflectivity of the reflectors results from the use of vacuum deposited aluminum or preferentially over-protected silver.

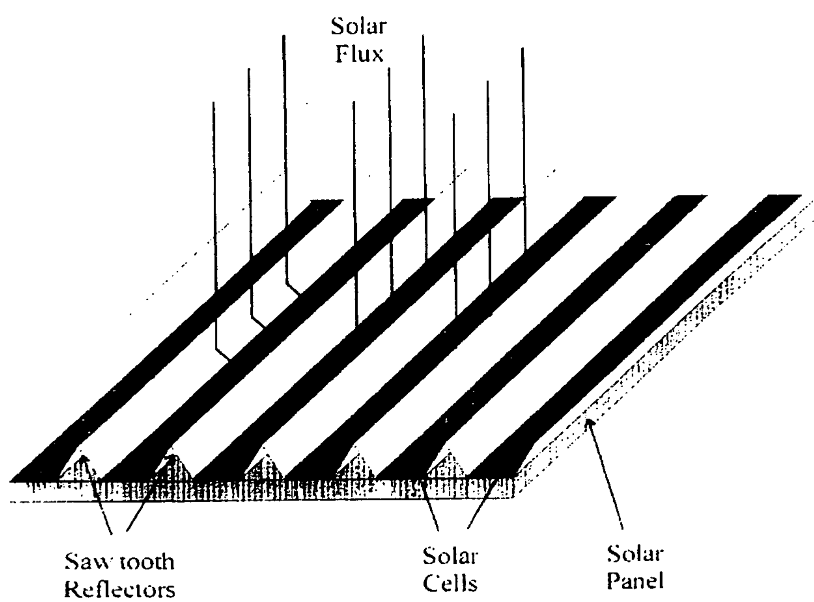


FIG. 1

EP 1 174 342 A1

Description

[0001] The present invention relates to a solar concentrator, particularly a space solar concentrator.

[0002] Spacecraft typically carries solar c lls as a primary energy. The solar cells are positioned and oriented on the spacecraft so that they are exposed to solar radiation.

[0003] On body-stabilized spacecraft, solar cells are typically arranged in planar arrays and carried on solar wings which extend from opposite sides of a spacecraft body. Preferably, the solar wings rotate to keep them as orthogonal to the solar radiation as possible. Because the solar wings can be quite long in their deployed configuration, they are generally formed of a plurality of planar solar panels which are coupled together in an accordion arrangement (one-dimensional deployment) or in a paving arrangement (two-dimensional deployment) so that they can be collapsed to a smaller stowed configuration for spacecraft launch.

[0004] The number of solar cells that must be carried by a spacecraft is a function of the anticipated spacecraft power demand and the efficiency of the solar cells. Although high-efficiency solar cells reduce the number of cells required by a specific spacecraft, they are quite expensive. Because weight and weight-related costs also increase with the number of solar cells, there is a considerable incentive to reduce the quantity of solar cells that a spacecraft must carry.

[0005] Accordingly, efforts have been extended to concentrate solar radiation upon solar cells by using reflective surfaces that are positioned adjacent to solar panels and oriented to reflect additional radiation onto the cells. Solar radiation that would otherwise have passed by a solar wing is thus redirected to be incident upon the solar cells. Although a solar cell's efficiency in conversion of this additional reflected radiation to useful energy is typically less than it is for the directly incident radiation, primarily due to increased cell temperature and decreased angle of incidence, solar concentration allows the number of spacecraft solar cells to be significantly reduced with consequent savings in spacecraft weight and cost. Both rigid and flexible reflectors have been proposed for solar radiation concentration with flexible reflectors generally having a weight advantage. An exemplary flexible reflector system is shown in U.S. Pat. No. 6,017,002 and 6,050,526. An exemplary rigid reflector system is shown in U.S. Pat. No. 5,520,747.

[0006] Although these reflector systems concentrate solar radiation, their positioning adjacent to solar panel give rise to several drawbacks. The solar cell temperature increases and consequently the power conversion efficiency decreases. The pointing errors induces lack of flux uniformity on the cell panel and the power management is complicated, consequently decreasing the panel electric power collection. The reflector position and deployment is not easily compatible with a two-dimensional deployment (paving-type panels) but only with a one-dim nsional deployment (accordion panels). Reflectors described in U.S. Pat. No. 5,520,747 presents another pertinent drawback. The solar reflectors are stowed over the solar cell face of the solar panels. Accordingly, th y block the use of the solar pan ls during any period (e.g., a transfer orbit) in which the solar panels are in a storage position that prevents reflector deployment. Moreover, the entire spacecraft power generation can be jeopardized in case of failure during reflector deployment.

SUMMARY OF THE INVENTION

[0007] A solar concentrator according to the present invention is composed of a rigid solar panel with rows of solar cells and reflectors (saw tooth shape) alternatively attached to the panel. Preferentially, the reflectors are oriented at 60 degrees with respect to the panel to reflect solar flux into cells. Their size depends on the solar cell size. Ideally, the width is the same as the cell width. The length is the same as the panel element length. After deployment, reflectors collect and concentrate the solar flux to the cells. The resulting geometric concentration factor is approximately 2:1. Before deployment, one of the preferred embodiment uses reflectors folded on the panel substrate to keep the folded geometry as compact as the one reached by a classic rigid panel without concentrator.

[0008] The reflectors are made of thin film with metal deposited. In one of the embodiments, the film can be tight on a rigid light-weight frame with applied pre tension. In another embodiment, only half of the reflector is made of a film tight on a rigid frame. In another embodiment, the reflectors are made of rigid light-weight material like Carbon Fiber Reinforced Polymer (CFRP) or thin Nickel sheet. In another embodiment of the invention, the reflectors are made of thin film without rigid frame, bonded to the panel substrate at the edges or integrated in the panel structure. The film shape is produced by tension thanks to arms (possibly deployable) bonded to the panel and reaching the roof of the saw tooth reflector.

[0009] In the present invention, reflectors are replacing solar cell rows. The weight of GaAs solar cell is about 0.85 kg/m_. Including coverglass, connections and wires, the weight of a solar cell row is about 1.2 kg/m_. A thin film reflector is dramatically lighter. For instance, a 50 microns (2 mils) Kapton® film weight 71 g/m_ only. Even including mechanical parts, the weight of the solar panel is not increased by the addition of reflectors according to the invention. The reflective film can be made of other substrate than Kapton. For instance Mylar® film is a good alternative.

[0010] From the cost point of view, solar reflectors are less expensive than the equivalent solar cell area, which constitutes an additional improvement of the present invention.

[0011] Since body-stabilized spacecraft are equipped

with a one-axis tracking capability, the pointing is relatively precise in the ast-west plan (about ±2 degrees). No tracking is performed in the north-south plane. It results in a seasonal variation of the panel orientation with respect to the sun. About ±23.5 degrees variation occurs in the north-south axis. For that reason, concentrator are often linear, concentrating sunlight in the direction where tracking is performed. For that purpose, the present reflector rows are oriented along the north-south axis and concentrate solar flux in the tracking axis only. The trough reflector-type with a geometric concentration of 2:1 and reflectors oriented at 60 degrees reaches a collection efficiency loss of 10% when the off-pointing in the tracking axis is ±6.5 degrees. This never happens unless attitude control gets lost. Since no concentration is performed in the other axis, the seasonal variation has no significant influence on the solar flux collection, compared to solar panel with no concentration.

The use of solar reflectors integrated in the solar panel allows for a more versatile and modular design of the deployed solar panel, compared with the previous invention where reflectors are adjacent to solar panels (trough-type concentrators). Indeed, in the later case, the solar panel deployment will more easily happens in a one-dimensional sequence, accordion-type. It results a wide wingspan with alignment and control complexity. The present invention is still compatible with more complex deployment schemes like two-dimensional paving. The modularity is significantly improved compared to the previously mentioned inventions.

[0012] The thermal behavior of solar panel has to be considered with high degree of importance.

The trough-type concentrator increases the solar flux on the panel but there is no easy way to reject the additional heat. The cell temperature increases by 30-40 degrees resulting in an unwanted cell efficiency decrease. This is mainly due to the fact that the flux collection surface is increased by the reflectors but the cooling is still coming from the same area : the panel rear and front surfaces, which are facing the cold space environment.

In the present invention, reflectors are mounted on the panel, the solar flux is still concentrated by the same amount on the solar cell rows. However, the collection surface is not significantly enlarged. It remains almost identical to the non concentration panel surface where the cooling surface is the same as the sun irradiated surface. Only a small temperature increase is expected. The power conversion efficiency is better compared to trough concentrators.

[0013] With a one-axis solar tracking, 1 or 2 degrees off-pointing currently occurs. The solar flux distribution on the panel is perturbed. The distribution is no more uniform.

In a trough-type concentration panel, off-pointing will overexpose some cell rows and underexpose other rows. The photovoltaic cells perform the electric conversion. The produced electric current is directly related to the absorb d solar flux. Some cell rows will produce larger curr nt than others. The serial connection of c lls is not compatible with such a current variation. Unl ss large improvement of the pow r manag m nt is introduced, this non uniformity induces loss of lectric power collection for the whole panel.

The present invention does not suffer from this lack of uniformity problem. Since each reflector is acting on a single cell row, the off-pointing induces non uniform flux distributed along the width of each cell and identical for each cell. The cell power conversion is identically affected on each cell and on each cell row. The induced electric current is still the same for each cell. The power collection by serial connection is no more affected. Power management is unchanged compared to non concentration panel and no additional loss is observed due to the off-pointing.

[0014] High Reflectivity of the reflectors results from the use of vacuum deposited aluminum (VDA) or preferentially over-protected silver coatings. Other coatings can be investigated as long as high solar reflectivity is produced. In the cell response spectrum, the average reflectivity of aluminum film at 60 degrees incidence is about 89%. Silver coating protected with $SiO2$ optimized thin layer, for instance, enhances the average reflectivity in the same condition to 97%. The over cost is easily compensated by the solar flux collection improvement. The reflectors used in the present invention looks like narrow tape. The width is about the same size as the cell width (± 40 mm). Film quality like micro-roughness or shape accuracy is more tolerant or easier to accommodate than the large reflectors used in a trough-type concentrator (typical width ~2 m). This make the design and manufacturing of the film and support easier. It also could contribute to reduce the weight of reflectors.

BRIEF DESCRIPTION OF DRAWING

[0015] Figure 1 : conceptual view of the present concentrator. The reflectors looks like saw teeth in rows with solar cell rows in between.

[0016] Figure 2 :illustrates the prior art: the trough concentrator with reflectors adjacent to the solar panel.

[0017] Figure 3 :

A : Collection loss due to tracking error in concentration type described in figure 1 and 2.

B : Distribution of light on the solar panel resulting from 3 degrees off-pointing.

[0018] Figure 4 : Reflector film reflectivity with 60 degrees incidence for unpolarized light. The typical response of a multi-junction GaAs/Ge solar cell and the solar radiation spectrum are also depicted. The reflectivity of vacuum deposited aluminum and over protected ($SiO2$ 160 nm thick) silver is depicted for comparison.

[0019] Figure 5 : several embodiments of the present invention in deployed configuration:

A : saw tooth reflector made of thin film on a rigid light-weight Al frame
B : half of the saw tooth reflector identical to fig. 5A and the other half made of tight thin film only.
C : saw tooth is made of thin film only. Tension is produced by rigid arms at the roof top.
D : rigid panel including saw tooth reflectors with no deployment capability.
E : saw tooth made of inflatable structure. Deployment to the correct shape come from the inflation of the membrane reflector. Reflective coating is deposited on the membrane material.

[0020] Figure 6 : several embodiments of the present invention in stowed configuration (for launch).

A : embodiment of FIG. 5B in stowed position
B : embodiment of FIG. 5C in stowed position
C : embodiment of FIG. 5D in stowed position

DETAILED DESCRIPTION OF THE INVENTION AND PREFERRED EMBODIMENTS

[0021] Referring to FIG. 1, there is illustrated a solar concentrator following the present invention. Rows of saw tooth reflectors and solar cells are alternatively presented. They are mounted on the solar panel structure. This structure is usually made of an aluminum honeycomb with CFRP (Carbon Fiber Reinforced Polymer) face sheets on both sides. The solar radiation is incident on the panel. It will reach the solar cells either directly, either after reflection on the reflector coating. In the preferred embodiment, row width is identical for cells and for saw tooth reflector. The reflector inclination angle is set to 60 degrees with respect to the solar panel plane. At that time, the geometric concentration factor is 2:1. It means that two square meters of solar radiation are concentrated on one square meter of solar cells. Since high-efficiency solar cells are very expensive, concentration is very attractive to reduce the cost.
[0022] FIG. 2 depicts a trough reflector concept which reaches the same concentration factor. It is similar to the concept described in US Pat. N°5,520,747, N°6,017,002, and N°6,050,526.
[0023] Referring to FIG.1, the solar reflectors are made of thin film with metal coating deposited onto. The film can be Mylar® or Kapton® or any light-weight and mechanically resistant material. The film thickness depends on the required mechanical strength. Typical thickness from 0.5 mil (~13 microns) to 5 mils (~125 microns) are currently available. In the preferred embodiment, the material is Kapton® with thickness of 2 mils (~50 microns).
[0024] The use of solar reflectors integrated in the solar panel allows for a more versatile and modular design of the deployed solar panel, compared with the prior art where reflectors are adjacent to solar panels. Indeed, in the later case, the solar panel deployment will more easily happens in a on -dim nsional s quence, accordion-type. The present invention is still compatible with more complex deployment schemes like two-dimensional paving. The modularity is significantly improv d and the pow r gen ration can be easily adapt d to various l v l.
[0025] In the present invention, the collection surface is not significantly enlarged. It remains almost identical to the non concentration solar panel surface. The cooling surface is the panel rear surface which is facing the cold space environment. Since the sun irradiated surface and the cooling surface keep close values, only a small temperature increase is expected. The power conversion efficiency is better compared to trough concentrators. Indeed, in the prior art, the collection surface is almost doubled but the cooling surface remains the same. Significant temperature increase is observed (30-40 degrees Celsius). The cell efficiency is decreasing and the power generation is affected.
[0026] Thermal balance in the present invention is optimized by maximizing the cell cooling through an efficient radiative heat transfer with the rear side of the panel. This can be reached by using honeycomb with open cells, directly facing the cold space environment. Furthermore, in one of the presented embodiments (FIG. 5D), the reflector structural stiffness enhances the panel stiffness. The mechanical requirement of the panel can be reached with a lower honeycomb thickness. The weight is reduced and the solar cell cooling is enhanced.
[0027] The spacecraft pointing accuracy directly influences the design of solar concentrators. They need to be compatible with the range of variation of the sun ray direction with respect to the solar panel. Body-stabilized spacecraft are not equipped with north-south tracking capability. The seasonal variation is ±23.5 degrees. For that reason, concentrators are not designed to perform concentration on that axis. Sun tracking is performed on the east-west axis with accuracy in the order of ±2 degrees. Concentrators need to withstand slightly larger tracking errors for reliability insurance.
Referring to FIG.3, consequence of pointing error is depicted. The simulation is true for saw-tooth concentrator (FIG. 1) and trough concentrator (FIG. 2). The off-pointing axis corresponds to the east-west roll of the spacecraft only. FIG. 3A shows the collection efficiency versus the angle of incidence of sun radiation. The first reason of efficiency loss is coming from the cosine law. The projected area is decreasing with a cosine law when the angle of incidence increases. This is true for any surface inclined with respect to the sun and it is not related to concentration. It is the main reason of sun tracking on any stabilized spacecraft.
[0028] The second loss factor is directly related to concentration. It shows an efficiency drop-off to 50% when the solar concentrator is 30 degrees off pointing with respect to the sun. Zero collection occurs with 60 degrees off-pointing. FIG. 3B shows a realistic case when the off-pointing is only 3 degrees. The distribution of light in bet een two reflectors is depicted. This area

is occupied by solar cells. In the case of the present invention, referring to FIG. 1, this area is occupied by a row of solar cells. The normalized ordinate depicted in FIG. 3B corresponds with the width of each individual solar cell. In the case of the prior inv ntion, referring to FIG. 2, this area is the solar panel width, including several adjacent solar cells. The normalized ordinate depicted in FIG. 3B corresponds with the width of the solar panel. Any distribution non uniformity is reflected on the adjacent solar cells. Some cells will receive about 65% of the nominal flux. Power conversion will be affected by the same amount. The electric current generated by those cells will be 65% of the nominal current. Serial connections of cells require a high uniformity of generated current to collect the power from the whole solar panel. The non uniformity of light radiation will conduct to a significant decrease of available power to the spacecraft.

Referring to the present invention (FIG. 2), the non uniformity is existing too but at the cell width level only. The loss of light collection due to off-pointing is about 4.5%. The loss of cell power generation will be in the same order. Each cell will suffer from the same loss factor. The generated power is still uniform from cell to cell. The serial connection scheme is still perfectly valid and no additional loss is expected.

[0029] The reflective metallic coating can be either aluminum either silver, or any efficient solar reflective coating. Aluminum is commonly used thanks to its manufacturing easiness and its good resistance to space environment (mainly radiation). Silver is not radiation-resistant. It needs to be over-coated with a transparent layer. MgF2, TiO2, and SiO2 are good candidates. SiO2 is the cheapest and is perfectly fitting with the solar spectrum requirement. Due to the requirement for overcoating, Ag is not as straightforward to handle as Al. The reason of interest on Silver coated reflective film is due to its better reflectivity in the visible range. It is commonly admitted that VDA film gets a reflectivity of 89-91% and Silver film reaches 96-98% reflectivity under normal incidence in the visible spectral region. For the present application, we are interested in reflectivity at 60 degrees incidence instead of zero (normal incidence). The spectral range is not limited to visible : multi-junction GaAs/Ge solar cells are sensitive from 350 to 900 nm. The solar flux is not flat over this spectral region : maximum intensity is reached at 450-500 nm. Flux drop-off occurs in the UV range. Slower decrease is observed in the red and IR.

Referring to FIG.4, the reflectivity at 60 degrees of aluminum and protected silver film is depicted (unpolarized light). Silver protection is made of a 160 nm SiO2 layer. For understanding and calculation purposes, the solar flux spectrum and the photovoltaic cell response are depicted too (normalized under arbitrary units). Integral calculation were performed to find the average reflectivity of metallic films using solar flux spectrum and the photovoltaic cell response as weighting factors. The analysis proves an average reflectivity of 89% for Al and 97% for Ag+ SiO2. It results a solar en rgy collection gain estimated to 4% for the whole solar pan l. This is true for the present invention (FIG. 1) and for prior art (FIG. 2).

[0030] Several options for mounting the film on the solar plate are possible. It depends on the requirement for reflector deployment. Weight of the panel is directly influenced. Detailed description of film mounting is given in reference to FIG. 5.

[0031] FIG. 5A shows a single saw-tooth reflector (not in scale) made of a reflector film attached on a rigid frame. This frame insures rigidity and tension of the film. Pre-load is required to produce a satisfying flatness of the reflector film. Frame material can be aluminum or nickel, for instance. In a preferred embodiment, aluminum is used for thermal reason (thermal expansion fitting well with Kapton® film) and for light-weight reason (density~2.7 g/cm_). In the stowed configuration, reflector elements are laying on each other on the solar panel surface. Reflectors are not stored over the solar cell in order to allow for power generation during first phases after launch or in case of deployment failure. FIG. 5B shows another embodiment of the present invention with the same concentrator where only one slope is equipped with a rigid frame. The other one is made of reflector film only. In that case, the film is maintained under tension thanks to the attachment to the rigid frame which is blocked at the nominal open position. In the stowed configuration, the reflective film is folded under the rigid part. The weight of the film is very low (typically, 50 microns thickness : 71 g/m_). The major weighting parts are the rigid frame and any mechanical element required for deployment and locking. The use of only one frame and very simple deployment provides a lower weight for this second embodiment. FIG. 5C shows a third embodiment where the reflective film is maintained under tension within the correct flatness requirement thanks to rigid arms (possibly deployable/telescopic arms). The reflector film edges are bonded to the solar panel. Light-weight rigid arms or bended arches are producing the adequate pre tension at the middle of the film width.

Referring to FIG. 5D, this embodiment uses rigid saw tooth reflectors (no deployment capability). The rigid reflector is preferentially made of CFRP, which is the preferred material for the honeycomb face sheet of the solar panel. Reflective film like Kapton® with metallic coating is over coating the reflector parts. High stiffness, good material compatibility, and high reliability (no deployment) are characterizing this embodiment of the invention. The reflector weight is slightly higher than in previous embodiment but, since no deployment and locking devices are required, the overall weight is still very attractive. Since the solar panel thickness is about doubled by the integration of rigid reflectors, the stowing must be adapted, compared to classical panel. FIG. 5E shows the stowed configuration with 2 interlaced facing

panels. The ov rall thickness will be slightly enlarged. However, the rigid reflectors could also act as stiffening parts of the solar panel. If the panel structural design is adapted (for instance, lower honeycomb thickn ss), th total thickness of stow d panel could remain close to the original case (without concentrators). In that configuration, reflectors will provide a more efficient cooling of cells.

Referring to FIG. 5F, a new embodiment of the present invention uses inflatable structure to provide deployment with correct reflector shaping while inflated. Reflective coating is deposited on the inflatable body.

[0032] Obviously, many modifications and variations of the present invention are possible in light of the above teachings. It is therefore to be understood that, within the scope of the appended claims, the invention may be practiced otherwise than as specially described.

Claims

1. A solar concentrator comprising a plurality of reflective surfaces connected to a plurality of solar cells **characterized in that** each solar cell is alternatively connected to two reflective surfaces oriented to reflect solar radiation upon the solar cells.

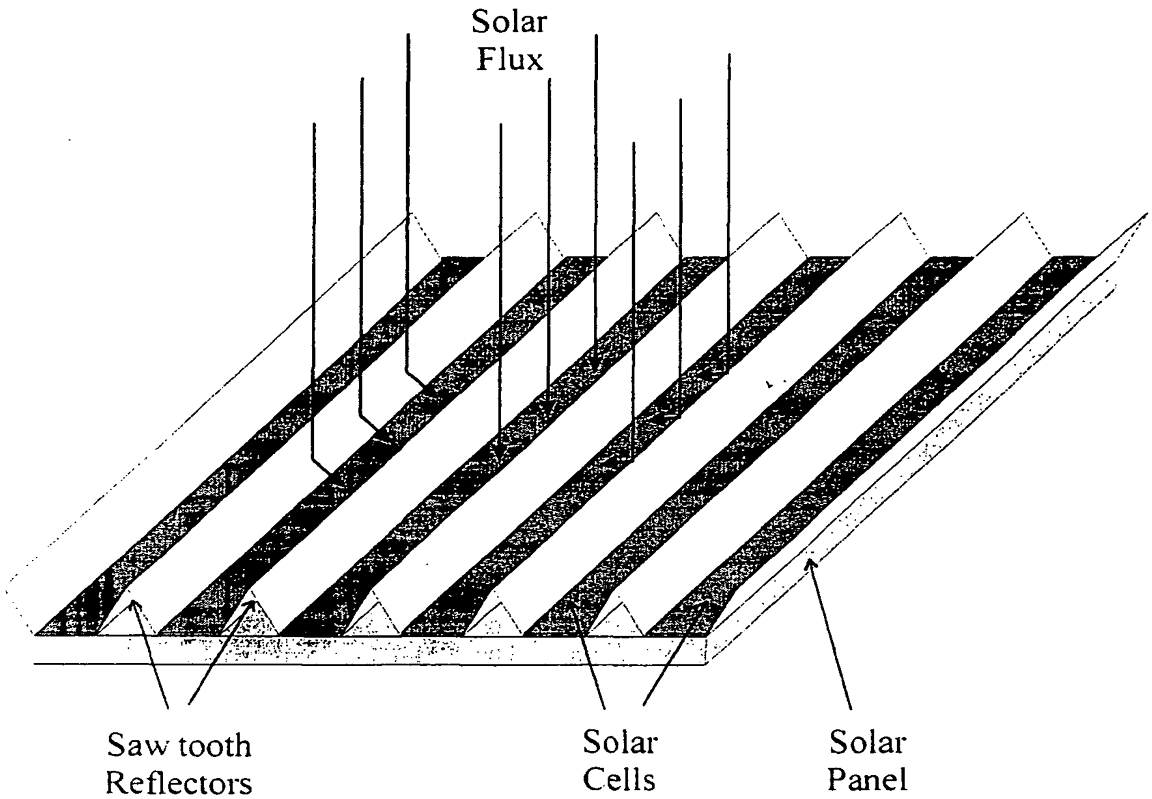

Solar
Flux
Saw tooth
Reflectors
Solar
Cells
Solar
Panel

FIG. 1

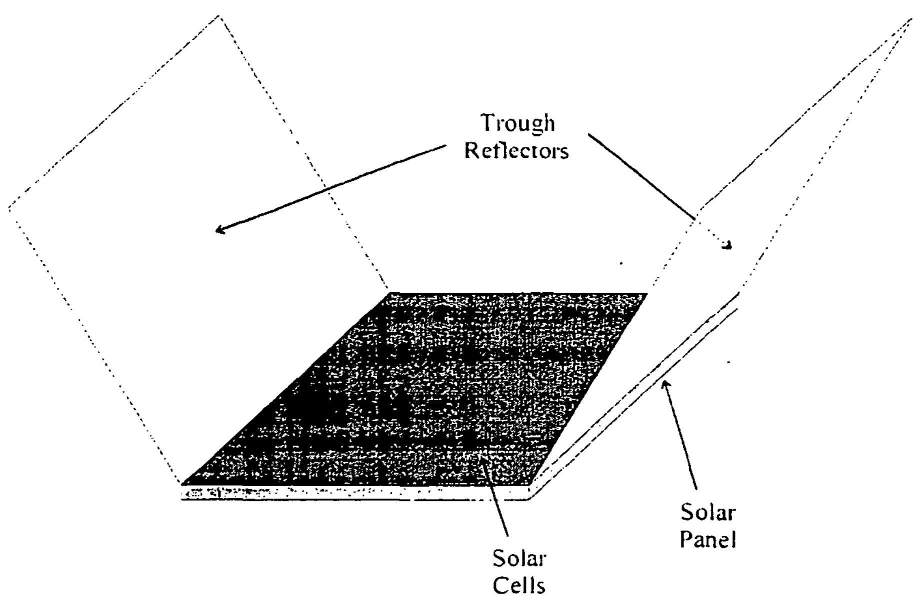
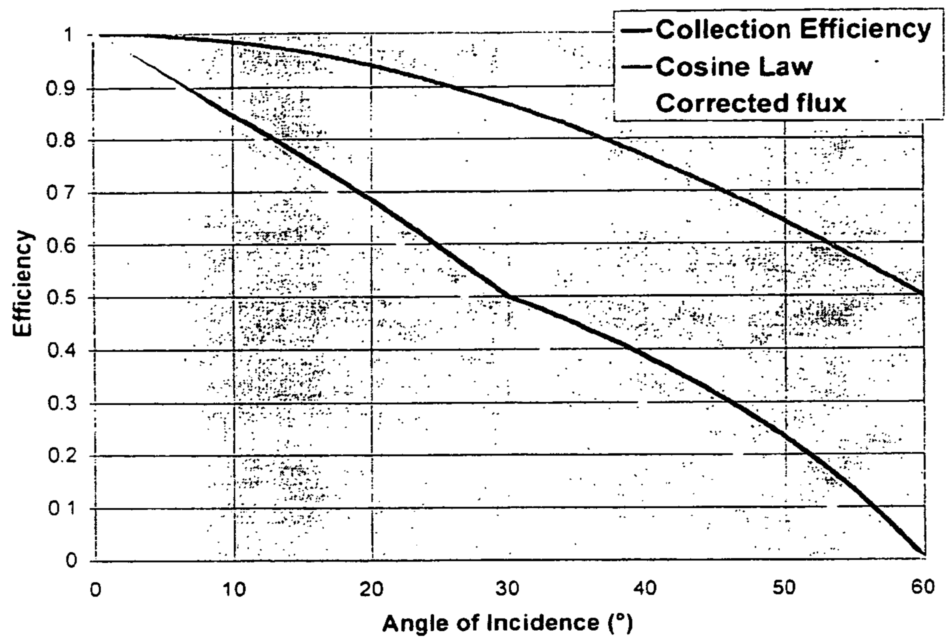
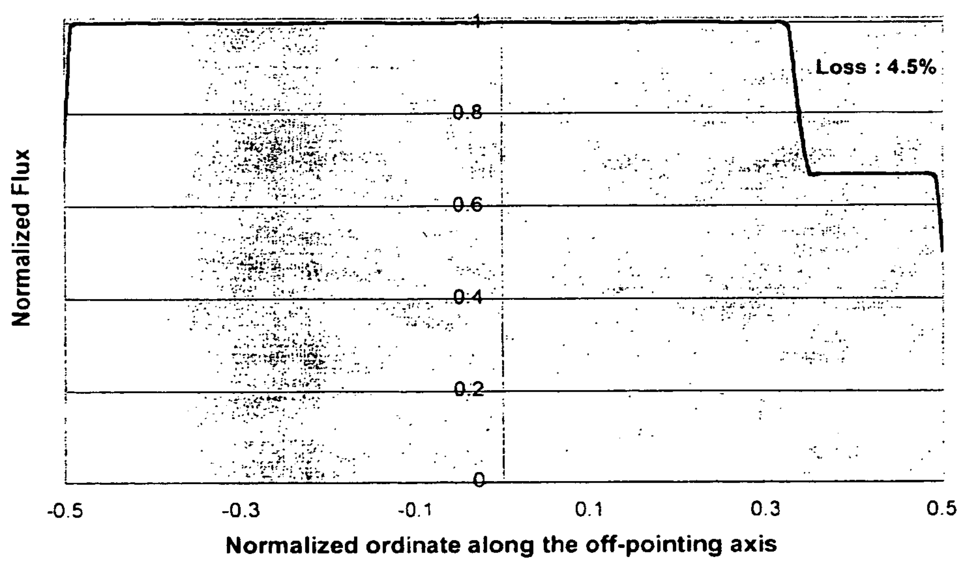

Trough
Reflectors
Solar
Cells
Solar
Panel

FIG. 2



Collection Efficiency
Cosine Law
Corrected flux
Efficiency
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
10
20
30
40
50
60
Angle of Incidence (°)

FIG. 3A



Loss : 4.5%
Normalized Flux
1
0.8
0.6
0.4
0.2
0
-0.5
-0.3
-0.1
0.1
0.3
0.5
Normalized ordinate along the off-pointing axis

FIG. 3B

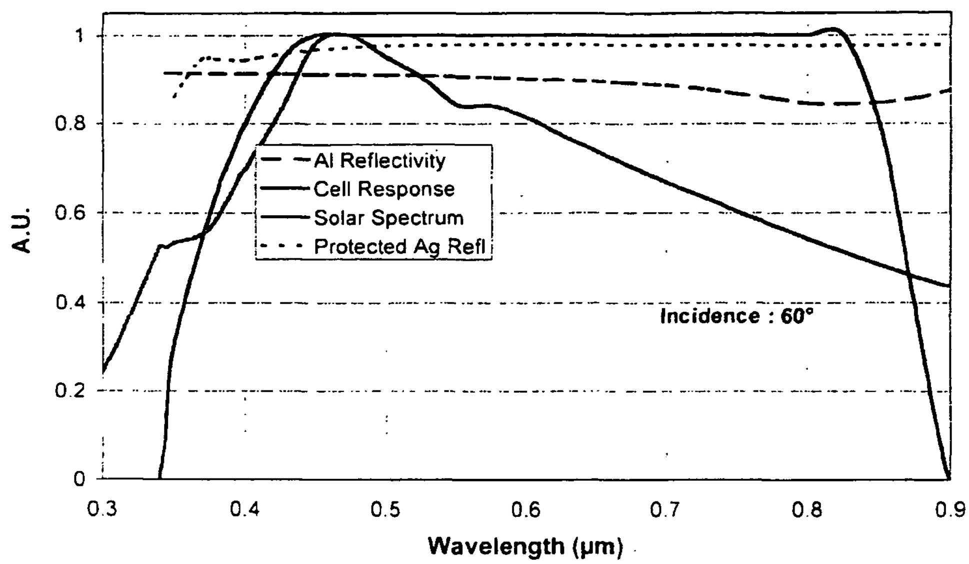

1
0.8
0.6
0.4
0.2
0
A.U.
0.3
0.4
0.5
0.6
0.7
0.8
0.9
Wavelength (μm)
Al Reflectivity
Cell Response
Solar Spectrum
Protected Ag Refl
Incidence : 60°

FIG. 4

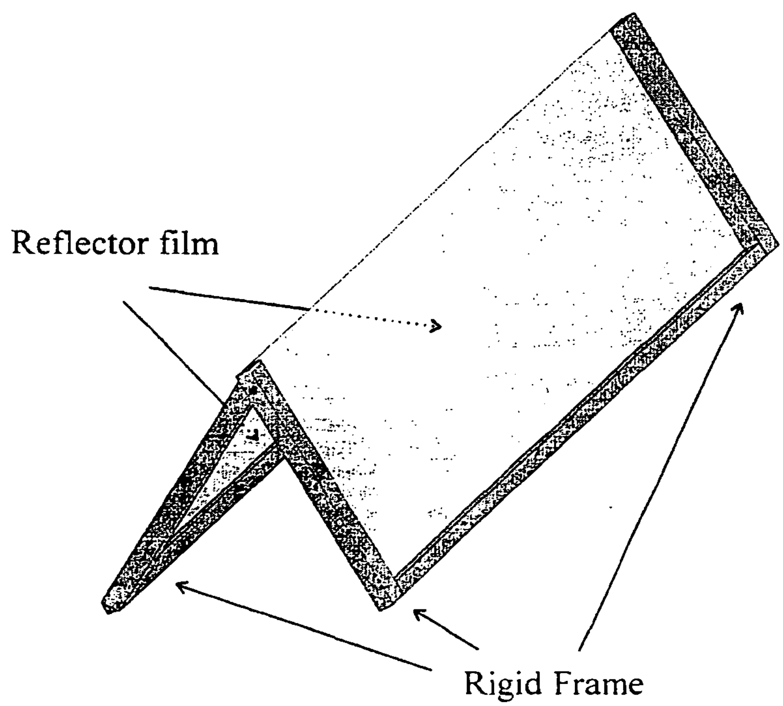

Reflector film
Rigid Frame

FIG. 5A

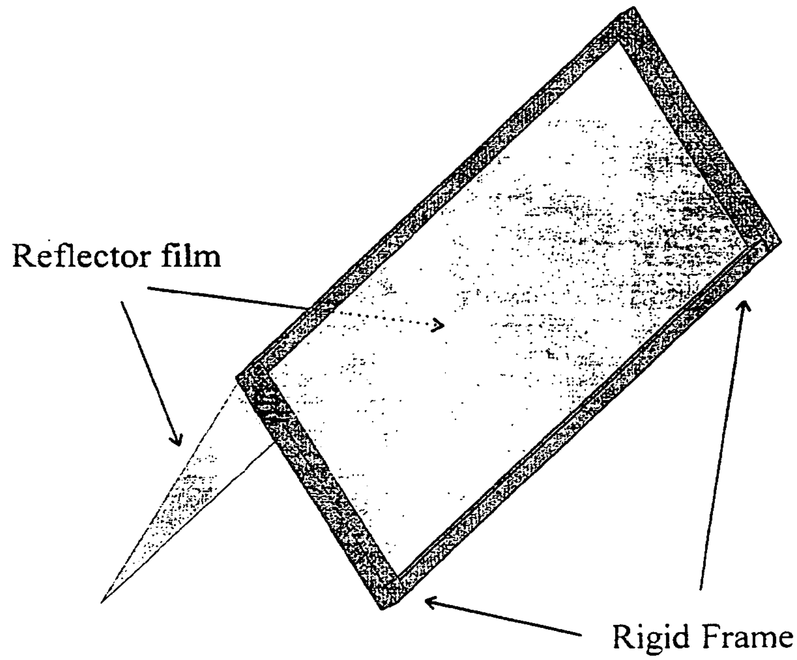

Reflector film
Rigid Frame

FIG. 5B

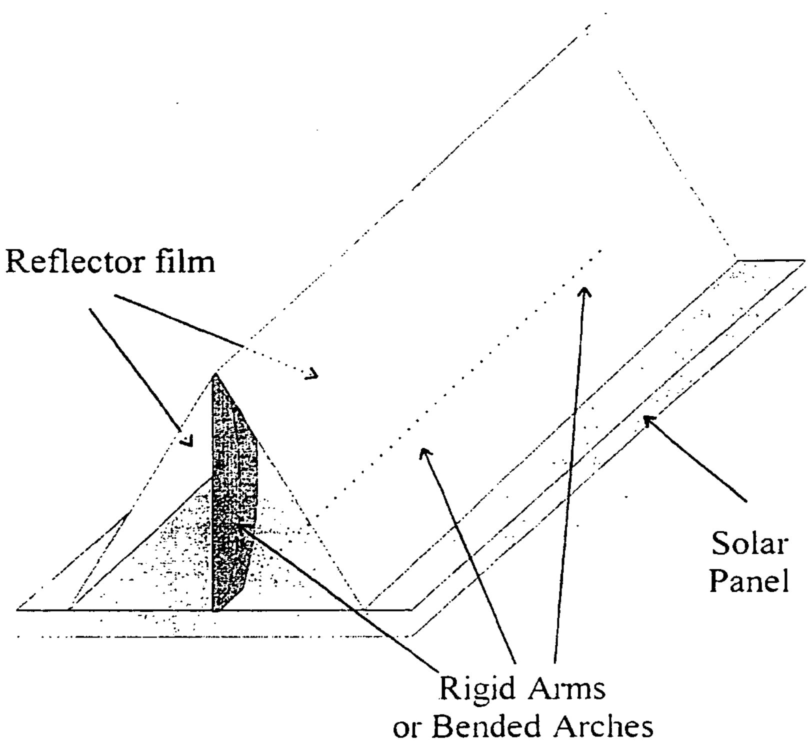

Reflector film
Solar Panel
Rigid Arms or Bended Arches

FIG. 5C

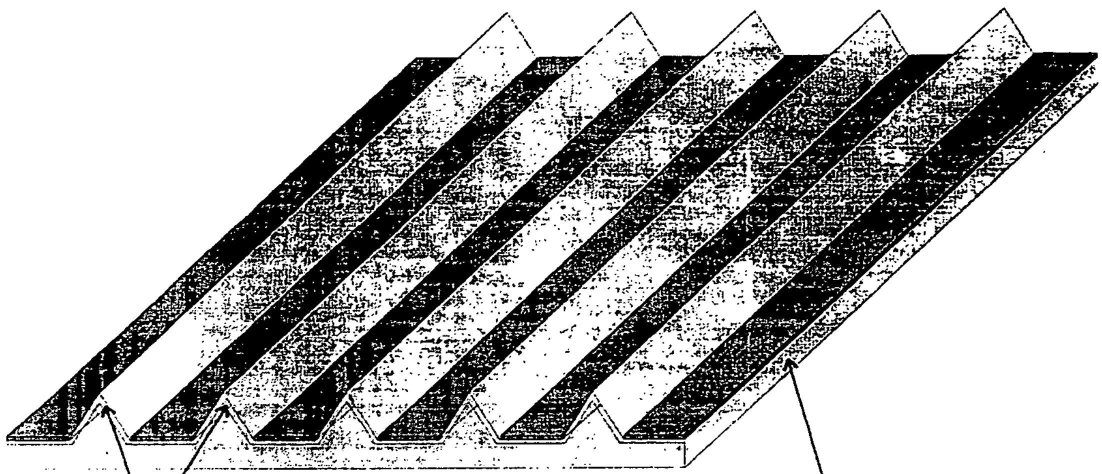

Rigid
Saw tooth
Reflectors
Solar
Panel

FIG. 5D

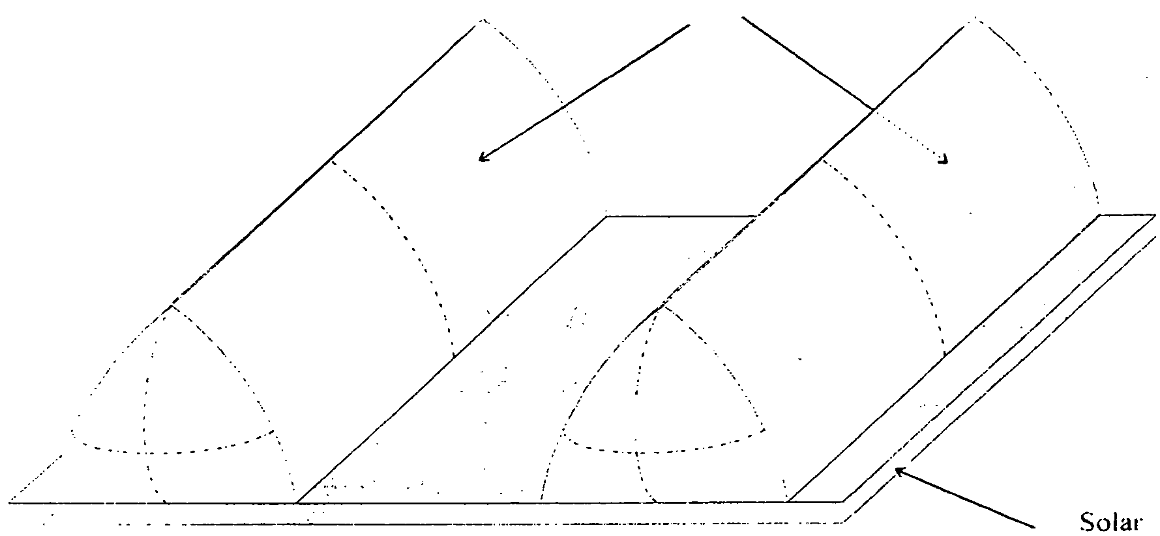

Inflatable Structure
with reflective coating
Solar
Panel

FIG. 5E

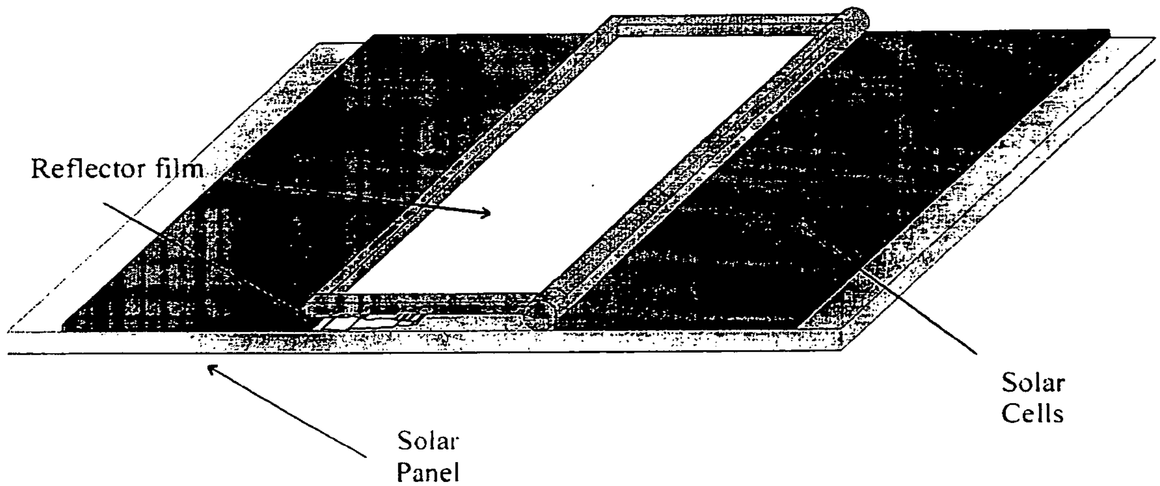

Reflector film
Solar
Cells
Solar
Panel

FIG. 6A

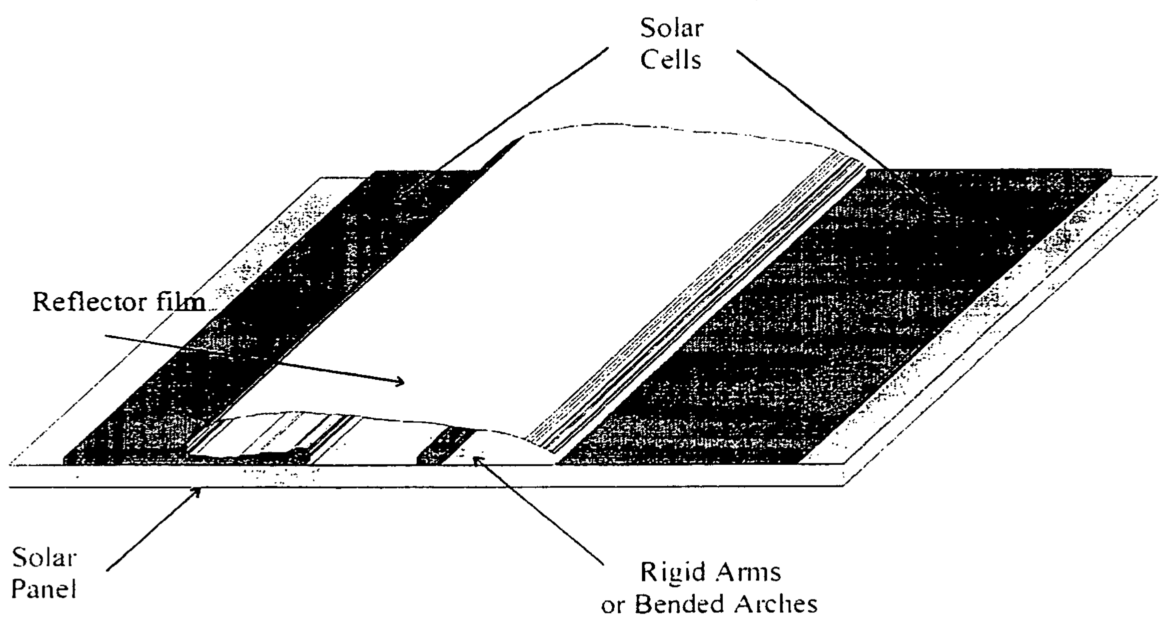

Solar
Cells
Reflector film
Solar
Panel
Rigid Arms
or Bended Arches

FIG. 6B

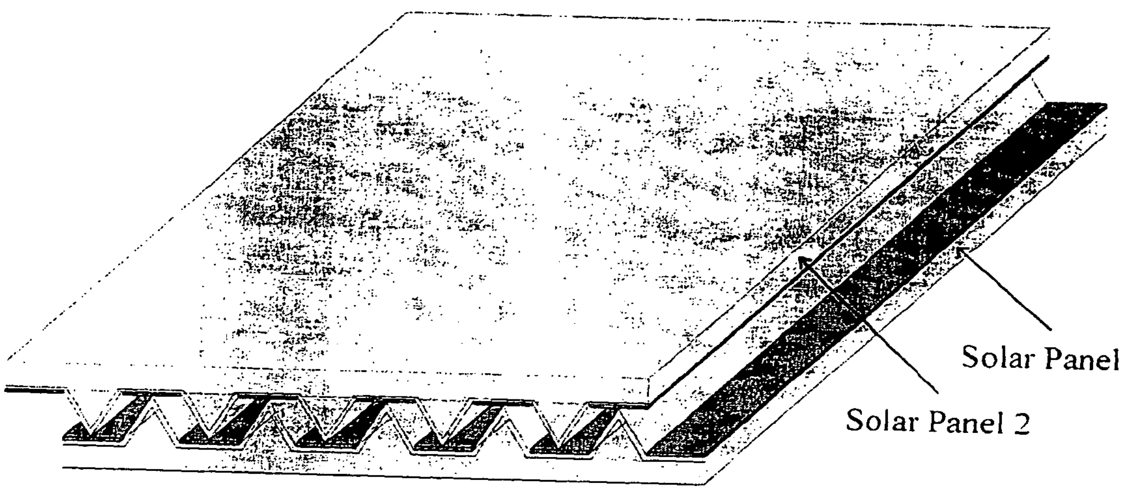


FIG. 6C

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 00 20 2669

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
X	US 3 350 234 A (ULE L A) 31 October 1967 (1967-10-31) * column 1, line 9 - line 49 * * column 4, line 25 - line 35 * * figure 2 *	1	B64G1/44 H01L31/045 H01L31/052
X	US 4 415 759 A (COPELAND ROBERT J ET AL) 15 November 1983 (1983-11-15) * abstract * * figure 16 * * column 9, line 49 - column 10, line 14 *	1	
D,A	US 5 520 747 A (MARKS GEOFFREY W) 28 May 1996 (1996-05-28) * abstract * * figures 1,5E,10 * * column 1, line 1 - column 2, line 62 * * column 3, line 56 - column 4, line 26 *	1	
D,A	US 6 017 002 A (BURKE STEPHEN D ET AL) 25 January 2000 (2000-01-25) * abstract * * figures 1,2C,3-5 * * column 1, line 6 - line 48 * * column 2, line 49 - column 3, line 10 * * column 4, line 32 - column 5, line 31 *	1	TECHNICAL FIELDS SEARCHED (Int.Cl.7) B64G H01L
D,A	US 6 050 526 A (STRIBLING JR RAY A) 18 April 2000 (2000-04-18) * figures 1,2C,3-5 * * column 1, line 27 - line 45 * * column 3, line 57 - column 5, line 62 * * column 6, line 20 - column 7, line 9 *	1	

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The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	29 November 2000	Calvo de Nõ, R

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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EUROPEAN SEARCH REPORT

Application Number
EP 00 20 2669

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
A	US 5 885 367 A (BROWN MICHAEL A ET AL) 23 March 1999 (1999-03-23) * abstract * * figures 1,2C * * column 1, line 1 - column 2, line 2 * * column 2, line 41 - column 3, line 40 * ---	1	
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TECHNICAL FIELDS SEARCHED (Int.Cl.7)

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29-11-2000

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